

## **MODIS Semi-annual Report (January 2000 – June 2000)**

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(This reports covers the MODIS **cirrus characterization and correction** algorithm and part of the MODIS **near-IR water vapor algorithm**)

### **Main topics addressed in this time period:**

#### **1. MODIS near-IR water vapor algorithm:**

**Science algorithm:** The near-IR water vapor algorithm is now working quite well in the MODIS operational computing environment. We can make routine process of all L1B data to produce L2 MOD05 near-IR water vapor products. We can also produce the daily L3 near-IR water vapor products on a global scale.

Some problems were present in our at-launch version of near-IR water vapor algorithm. One problem was that an incorrect array was written into the output L2 MOD05 HDF file as the near-IR water vapor image. This problem was fixed in late March of this year.

More recently, we found that the QA parameters written into the MOD05 HDF files were not correct. It took us quite a bit of time and efforts to identify the problems and to fix the problems. A new version of near-IR water vapor algorithm is undergoing thorough tests and will soon be delivered to the MODIS Project.

We produced nice-looking near-IR water vapor images from MODIS data. These images were used by NASA Goddard scientists and managers during various meetings and conferences (including the April 19 NASA Press).

**Validation:** Preliminary work on validation of the MODIS near-IR water vapor products has been conducted by Richard Ferrare at NASA Langley Research Center. Richard is a NASA-selected EOS validation scientist. He compared water vapor measurements obtained from ground-based upward-looking instruments with near-IR water vapor values derived from MODIS data over a DOE ARMS experimental site in Oklahoma. He found that the correlation between MODIS near-IR water vapor values and those from ground-based measurements is greater than the correlation between MODIS IR water vapor

values and those from ground-based measurements. Based on a very limited number of comparisons, we have found that the correlation between MODIS near-IR water vapor values and IR water vapor values is very weak. More validation work needs to be conducted in the near future.

## **2. MODIS thin cirrus reflectance and contrail algorithms:**

Our simple at-launch version of the MODIS thin cirrus reflectance algorithm works reasonably well. We are producing L2 thin cirrus reflectance products for each MODIS granules and L3 daily and global cirrus reflectance products. In this version of the algorithm, the two-way water vapor transmittance on the Sun-cirrus-MODIS path was estimated based on our previous experiences gained from analysis of hyperspectral imaging data acquired with the NASA JPL AVIRIS instrument (Airborne Visible Infrared Imaging Spectrometer). At present, we are slightly under-estimate the cirrus reflectances in the visible. Major progress has been made with deriving the 2-way water vapor transmittance on the Sun-surface-MODIS path from the scatter plot between the 1.38-micron channel image and the 0.65-micron channel image. We expect that an improved version of cirrus reflectance algorithm will be delivered to the MODIS Project in about 6 months.

From some of MODIS 1.38-micron images, we can see clearly aircraft contrails. The contrail algorithm was previously written by Bill Ridgway. Because of his involvement with many aspects of the MODIS Project, he didn't have time to work on the contrail detection algorithm. Additional work is needed to fine-tune a few parameters in the algorithm so that the algorithm is adapted to the MODIS data processing.

We produced spectacular images on detecting thin cirrus clouds with the 1.38-micron channel and correction of thin cirrus effects in the visible. Just as our water vapor images, the cirrus images were also used repeatedly by NASA scientists and managers during various meetings and conferences.

Our thin cirrus reflectance algorithm is empirical in nature. We didn't conduct any field experiment to verify our cirrus reflectance products. Our validations are largely based on visual inspections of cirrus-corrected visible images (obtained by subtracting the cirrus reflectance image from the MODIS measured visible images) to see if we over- or under-estimated cirrus effects. Our brains are very effective in image processing. The over- or under-corrections of cirrus effects can be easily detected through such visual inspections.

### 3. Visualization

In order to view MODIS L1B, L2, and L3 imaging data stored in HDF files, we adopted many routines written by Mike King's research group at NASA Goddard and Paul Menzel's group at University of Wisconsin. We wrote IDL routines to re-order MODIS data in band-sequential-format and in the order of ascending wavelengths. The resulting images can be viewed quite easily in either spatial domain or spectral domain using commercially available software packages. We wrote IDL routines to convert satellite-measured radiance images to apparent reflectance images. We wrote IDL routines to produce nice-looking L2 and L3 water vapor and cirrus reflectance images. We wrote F90 routines to read individual QA parameters (in one bit or more than one bit) packed inside a byte array. The F90 routines allowed us to uncover the errors in QA parameters written into MOD05 HDF files.

### 4. Data Analysis

The detection of polar clouds over bright snow surfaces was traditionally very difficult from data acquired with meteorological satellites (such as those of the AVHRR series). We have found that such clouds can be easily detected from the MODIS 1.375-micron images. The reasons are that, at 1.375 micron, the snow and ice-covered surfaces are quite dark due to large particle sizes and strong ice absorption. The particles in cirrus clouds and water clouds in the polar region are much smaller than snow and ice particles on the surfaces. The solar radiation at 1.375-micron scattered by clouds can be detected by the MODIS sensor. As a result, the 1.375-micron channel detects clouds over dark surfaces in the polar region. We feel that the MODIS data will greatly improve our ability in remote sensing of polar clouds.

Before the launch of the Terra spacecraft, there was a concern about the low signal to noise ratio for the 0.935-micron water vapor channel (originally proposed by Albert Arking). We examined the real MODIS images of this channel, the signal to noise ratio is comparable with other near-IR water vapor channels. As a result, we still use this channel in our near-IR water vapor algorithm. The striping and calibration problems with the 1.24-micron MODIS channel slightly affect our near-IR water vapor retrievals.

The MODIS channels centered at 1.24-, 1.64-, 2.13-, and 1.375-micron are likely affected by optical and electronic cross talks. MODIS MCST should make proper characterizations and corrections of the cross-talking problems. Unfortunately, MODIS MCST has not yet conducted the work necessary for the corrections.

We found that some MODIS land channels in the visible can be saturated over bright clouds near the equator.

We also found that MODIS ocean color channels (in 0.6 – 0.9 micron spectral region) specifically designed for the purpose of correction of aerosol effects in the visible are saturated under medium hazy to hazy conditions. The presence of thin cirrus clouds or a small piece of cumulus cloud within a pixel can easily saturate these channels. If the saturation levels of these channels were set higher, these pixels could still be useful for ocean color studies. The Japanese GLI instrument closely followed the MODIS channel specifications. The saturation problems with the atmospheric correction channels on GLI for ocean color studies are comparable to or even slightly severe than the MODIS channels. At present, the MODIS Ocean Group does not feel that the saturation levels of MODIS ocean color channels in 0.6 – 0.9 micron spectral regions were set too low. They feel that if a pixel is saturated at 0.86-micron, the pixel should be simply thrown out. The problem is that, in the pursue of purest and cleanest pixels, too many pixels are thrown out and the L2 ocean color images are often quite patchy (having many holes due to the saturation effects).

## **5. Radiative Transfer Modeling:**

Ping Yang has also been studying the scattering properties of cirrus particles. In particular, in collaboration with Bryan Baum from NASA Langley Research Center, Andy Hemsfield from NACAR, and Shaima Nasiri from CIMSS/University of Wisconsin, he is developing new cirrus scattering database that will be directly related to the retrieval of cirrus optical and microphysical properties from MODIS data. At this, the replicator data regarding the sizes and shapes of ice crystals are being analyzed and new cirrus models in terms of size distributions and habit percentage for warm, cold, and cirrus oncinus will be developed. He will further calculate the single-scattering properties for the integration of the size distribution. Eventually, a new scattering library will be provided, which will replace the current MODIS ice particle scattering library that was calculated by him a few years ago.

## **6. Meetings**

Gao, B.-C., attended the AGU Spring Conference held in Washington, DC during May 30 – June 3, 2000.

Most of us attended the MODIS meeting June 7-8, 2000, which was held in Holiday Inn College Park.

## 7. Publications

- Gao, B.-C., A practical method for simulating AVHRR-consistent NDVI data series using narrow MODIS channels in the 0.5 - 1.0  $\mu\text{m}$  spectral range, *IEEE Transa. Geosci. Remote Sens.*, 38, 1969 – 1975, 2000.
- P. Yang, B.-C. Gao, B. A. Baum, W. J. Wiscombe, Y. X. Hu, S. L. Nasiri, P. F. Soulen, A. J. Heymsfield, G. M. McFarquhar, and L. M. Miloshevich, Sensitivity of Cirrus Bidirectional Reflectance at Two MODIS Bands to Vertical Inhomogeneity of Ice Crystal Habits and Size Distributions, *J. Geophys. Res.* (submitted).
- P. Yang, B.-C. Gao, B. A. Baum, Y. X. Hu, W. J. Wiscombe, M. I. Michael, D. M. Winker, S. L. Nasiri, Asymptotic solutions for optical properties of large particles with strong absorption, *Appl. Opt.* (submitted).
- Gao, B.-C., M. J. Montes, Z. Ahmad, and C. O. Davis, Atmospheric correction algorithm for hyperspectral remote sensing of ocean color from space, *Appl. Opt.*, 39, 887-896, 2000.